Carbon & Hybrid Technology

By: A.J. van den Hul CD

First a short discussion on metal conductors and their vulnerabilities:

Due to the current cable manufacturing processes based on economics and aging, all metal conductors are sensitive to growing chemical boundaries at the edges of their internal crystals.
These chemical boundaries form non-linear conductive barriers for the electrical signal to be transferred.
The main reason for the origination of these chemical boundaries is the rough industrial handling of the basic material during the manufacturing of the single leads by pulling the metal through many dies and the unprotected storage in between. Especially the bare storage of the drawn wires on reels in the open air creates another problem: chemical interaction with airborne reactive components and their subsequent deeper propagation into the metal during the next processing steps.
As you can imagine, the result is that the final conductor still looks like a conductor, but on microscale does not exactly behave like one anymore.
There is no continuous and stable/predictable conductive medium from the begin to the end of e.g. an audio cable. Thanks to the mechanical and (even unknown) chemical treatment of the product during manufacturing, but also its handling and storage afterwards, in the mean time a lot of new crystal boundary contamination will have sneaked its way into the metal, this causing all kinds of audible side-effects like sonic harshness and masking of spatial information.
I have named this: **Cross Crystal Distortion** (**CCD**).
The size of the crystals in general after production will range from big (around max. 1 mm.) to small (like 100 µm.). The more crystals, the higher the number of crystal boundaries and the stronger the CCD effect.
This is the main reason why metal conductors (especially audio cables) age and with it change their sound character.

It's man's eternal task to rework (recycle) waste to the actual highest standard; and the whole process starts again. Forgetting the aspect of recycling for a while, the practical effect for an audio freak is that he has to renew his cables every once in a while. This is the result of his (mostly unconscious) awareness of the cable's growing harshness and fading detailedness. The smooth detail is replaced by the artificial harmonic distortion caused by CCD. In some occasions this would just be the effect audio-freaks are looking for. Therefore around the world we see some different lines of products produced with the simple reason to match these differences in "audio taste".

Impurities in the basic metal, copper or silver, will act as trigger points for growing CCD inside the (cable) product.

Q: What generates the typical mechanical defects in a metal conductor like e.g. a copper cable?

A: During the production of the conductor there is a lot of mechanical processing like stretching and bending.
Any bending causes minute surface cracks to appear at the outer side- and displacements on the inner side of the curvature. Each break or displacement exposes metal crystal boundaries to reaction with gases from the air (e.g. Oxygen). So there is an outer layer full with impurities (like metal-oxides), non-continuous structures and dislocations. Afterwards it is a miracle that there is still conductivity left.

Q: What are the sonic effects of these defects?

A: As soon as a conductor is not a uniform material, each zone or layer has its own electrical influence on the sound. Especially at lower signal levels, there is a growing influence (the aging effect) on the transmission of the electrical signals (music).
The result is that especially the spatial information drops out and gets replaced by harshness.

Q: What causes this so called "harshness"?

A: The harshness is the result of the abrupt raise in the electrical impedance caused by the growing lack of conductivity at lower signal levels. Very low level sinewaves (tones in the audio signal) e.g. will experience zero crossing nonlinearities and due to this will be supplemented with a rich quantity of (unnatural) harmonics. The zero crossing parts of the sinewave perish since there the signal does not have enough energy to take the (polluted) crystal barriers.

Q: Is there any difference between e.g. copper and silver conductors besides their color and price?

A: In principle the answer is NO. But despite this NO there are some differences in the processing. Silver costs a lot more than copper, so the general production attitude is more careful and the production speed is lower: less meters per second, resulting in a reduced mechanical and chemical aging. Sonically this works towards a better signal quality transmitted along the product. The influence of air and bending on the product after its manufacture is about the same as copper, so

the aging in a listening room is not different.
Only when the owner is very careful with the product (no bending and a clean atmosphere) the cable will sonically “live” longer.
The crystal structure of e.g. copper and silver is equal and their number of free electrons per volume are about the same. So their typical resistance is equivalent, should this property be important to you.

Q: Is there a difference between various conductors on an atomic scale?

A: Yes indeed. The differences on atomic and crystal scale among various metals give rise to their distinct physical properties like hardness, ductility and electrical conductivity. The conductivity being determined by the amount of free electrons available per volume and their freedom to move along the atomic grid.
Especially the electrical current’s freedom of movement is impeded by all kinds of structural disturbances like crystal (grain) boundaries which give rise to increased and signal dependent electrical resistivity.
Regarding audio applications it is therefore important to work with conductor materials which exhibit and maintain an as little disturbed structure as possible.

Q: Does a higher resistance influence the sound quality?

A: It is not so much the value of the resistance but rather its quality that is important. A stable resistance of the conductor is much more welcome than a resistance depending on the level of the passing signal. In the first situation the sound quality is ok. In the last situation again we get a strong CCD effect, and the sonic result is a signal dependent harshness and a lack of detail, the latter replaced by non coherent harmonic distortion. The non coherent character is related to the harmonic structure of the music.

Q: Can different metals be combined to produce a good sound?

A: As long as each metal more or less has the same defects, the result will not be better compared to a single metal construction.
Conductors made of copper, brass and silver to reproduce the sound of a brass band is a nice idea but nothing more than that.

Q: What is the influence of coating copper conductors with a silver layer?

A: This depends on the way the coating is achieved. When the coating is done by e.g. electro plating in a liquid containing silver ions (a bath containing a dissolved salt of silver and other chemicals), residual components of the carrier liquid will remain between the growing silver crystals.
This unpredictable “soup” will immediately start chemical activity in any wet or humid environment. So instead of the noble silver forming a protective layer, the copper is surrounded by a chemical unfriendly environment; the result is that the copper conductor will age much faster. The sonic result is extra attention on high frequencies with an unnatural character caused by extra CCD.
So cables coated with silver by an electroplating process will never sound better than their plain copper.

Q: Are there any good solutions?

A: Yes there are. Coating metal by means of mechanical processing like cladding is a solution when we think about pure metal cables. So mechanically silver or gold plating a copper conductor is the best solution, besides of course a very good electrical (non PVC) isolating jacket applied immediately after the last die.
Another very good solution is vacuum sputtering a silver or gold layer on a very pure copper conductor. But this is a costly operation.
Our company has products in its program which are manufactured after these principles. Both by the industry and hi-fi lovers they are evaluated as sonically very superior.
Especially our SCS series of multistrand single leads (like e.g. SCS - 2, SCS - 4, SCS - 6, SCS - 12, SCS - 16, SCS - 18 and SCS - 28 M) and our quadruple lead The SUPER NOVA are typical products made according to this philosophy.

The regular “wet” electroplating can still be improved by adding extra process steps like ultrasonic cleaning in distilled water after each production run. The distilled water must be replenished frequently, otherwise the ion contamination effect will remain.
In our program we have products like the CS - 12 HF, CS - 14, CS - 14 HYBRID, CS - 16 and CS - 18 which are manufactured with this production idea in mind.

It is very important that during the electroplating process the copper is not bent or stretched; this highly reduces the absorption of ion residues in gaps on the outer surface. In this manner the extra fast aging due to this absorption is prevented. In our production procedure a lot of attention is paid to this typical manufacturing aspect.

Q: Are there other practical solutions?

A: Yes, just forget metals. As long as metals are selected for the practical reason that they are cheap and easy to work with, all problems involved are induced over and over again, despite all extra efforts involved.

Q: What other materials can be used as conductor?

A: After a lot of research our solution is non-metallic: very pure strings of carbon-saturated fibers.
With this material there are many advantages compared to any metal.

1. The mechanical aging is finished because the type of carbon structure used by van den Hul is, by its size already (each fiber is 6 micron thick), insensitive to bending.
   Metal conductors used in audio have a minimum diameter of 25 micron and often are much thicker.

2. The mechanical strength is such that e.g. pulling the fibers will not cause any internal displacements or boundaries.

3. The carbon structure we use is also thermally completely stable. Even at temperatures of 2000 degree Centigrade there is no chemical activity like the production of CO or CO_2.

4. Also there is no interaction with any chemical known so far. Under standard conditions of audio use this means that the lifespan is unlimited without the material changing its structure or properties.

Q: How is this carbon material called?

A: We call it **L**inear **S**tructured **C**arbon ® or **LSC**.
Linear, because the electrical output signal is exactly the same as the original input signal.
Structured, because the carbon's atomic grid structure is defined by the processing of the basic material. This is a special property because the carbon normally used in the audio industry is based on random orientated carbon powder.

Q: What is this material made of?

A: We start with very pure carbon, and thanks to a special processing we are able to line-up all carbon atoms in one big molecule without any boundaries or barriers.

Q: How does this LSC behave electrical?

A: Very superior compared to metals:

1. Each of the 6 micron thick fibers has its own electrical insulation. The common effect with multistrand metal conductors is that electrons can also go from strand to strand and with that cross many more boundaries. Our individually insulated fibers do not exhibit that effect; electrical signals entering a fiber come out of the same fiber.

2. Thanks to the stable structure of the LSC, mechanical aging and chemical pollution/deterioration are finished for ever. The carbon atoms are very tightly (and therefore stable) positioned in the LSC's atomic grid.

3. The electrical impedance is independent of signal level. So the typical addition of harmonics due to CCD is past history. This directly implies a much higher acoustical resolution on very low signal levels.

Q: Are there any patents involved with LSC?

A: Yes, in many countries we own patents to protect our unique position with LSC.

Q: How does LSC "sound"?

A: When applied as an audio product, the "sound" is more natural and detailed compared to any metal cable.
The transfer of spatial information is strongly improved and the (with metals) typical distortion on the high frequencies makes way for a very natural and mild character, equivalent to live sound.
The often required hi-fi qualities in a soundsystem with extra pitch are out. Back is fatigue-free listening!
This fatigue-free listening originates from the fact that with LSC all frequencies stay in phase and maintain their harmonic structure. The brain does not need to filter-out or rework the (with metals) extra unnatural harmonics.

Q: Is there any problem with so called "Time Delay"?

A: There is no problem at all. The random woven individually electrically insulated fibers all have the same length. The typical "Skin Effect", commercially often used as an argument by cable manufacturers, does not exist with this material

(LSC). Also, signal reflections caused by eventual impedance mismatch at a LSC cable's terminals are effectively dealt with: the individual LSC fibre's resistive properties bring about an excellent reflection damping.
All our products made from LSC are essentially free from timesmear and/or time delay.

Q: LSC exhibits a higher electrical resistance compared to e.g. copper. Are there any disadvantages?

A: The higher resistance of LSC is its only minor disadvantage. From all materials we know, LSC exhibits the best balance in mechanical, chemical and electrical stability. So we have accepted its somewhat higher resistance as the only minor property we have to live with.
LSC's higher resistance produces only a minor disadvantage in low impedance circuits where it causes a small signal attenuation. When the source impedance of a preamplifier e.g. is 100 Ohms and the input impedance of the power amplifier e.g. is 50 kOhms, a 3 meter length of our cable The SECOND ® in balanced configuration will cause a mere attenuation of 0.037 dB itself .
Compared to the much bigger unbalance of volume-controls we can ignore this figure.

Q: How does one make an electrical connection to LSC fibers?

A: At the moment we do this mechanically. First all individual fibers are de-insulated using a solution of acetone and an other agent. After this process we clamp the group of fibers in special made small connectors which subsequently are soldered into the final audio connector.

Q: Does this extra electrical connection affect the sound quality?

A: We use very high quality copper with a pure 24 carat gold plating, the best there is out of the traditional world. The total length of the fibers crimped into these small connectors is 1mm. for both ends together. A standard cable is around 1 meter or longer, so only 1 per mill of the total length is in direct contact with the metal.
The small end-connectors are pressed rather flat, so many fibers of the total 12.000 are in direct contact with the clip's soft gold layer. This involves hardly any “take-over” impedance and therefore also no transmission losses.

Q: What products in your audio cable range make use of pure LSC at the moment?

A: In our current program we have five cables carrying the names:

The FIRST ®, The FIRST ® Ultimate, The FIRST ® Metal Screen, The SECOND ® and The THIRD ®.

1. The FIRST ® is a coaxial (single ended) construction with 12.000 fibers in its core and 38.000 fibers as its screen. It was, as the name already indicates, our first product with LSC, originating from August 1993. Because of the resistive character of the product it also works well as a digital cable.
   The reason of this is that the natural damping of the center group prevents standing waves (signal reflections), so the decoder (in the Digital to Analog Converter DAC) has no problems with the clock recovery. The characteristic impedance of The FIRST ® is 110 Ohms at 10 MHz and 90 Ohms at 40 MHz, so the transmission of higher frequencies is somewhat easier, compensating for initial losses and meanwhile sharpening the digital interface signal's edges.
   Thanks to the pure LSC construction of The FIRST ® it is the best example of quality transmission available in interlinks.
   A small hint: don't use The FIRST ® in combination with valve power amplifiers with power transformers that radiate strong magnetic fields; this will cause minor hum problems. The FIRST's shield resistance is 14 Ohm/m instead of the (with metal cables) usual 0.01 Ohm.
   The FIRST's outer jacket is made of HULLIFLEX ®, a superior halogen free insulation material without any electrical dipoles.

   Please note: Our The FIRST ® now has been discontinued. **—A.J. van den Hul B.V.**

2. The FIRST ® Ultimate is a threefold heavier shielded version of The FIRST ®.
   The FIRST ® Ultimate's outer braiding, functioning as screen and signal return, is made of 6 (instead of 2) layers of braided LSC fibres. Exhibiting all excellent qualities as found in The FIRST ® at a much reduced shield resistance, its susceptibility to hum is very low. The FIRST ® Ultimate therefore is applicable in the most demanding analog and digital audio applications.

3. The FIRST ® Metal Screen has the same basic construction as our The FIRST ® but is additionally equipped with a metal shield. The FIRST ® Metal Screen with its extremely low shield resistance has been specially designed for those situations where excessive ground currents flowing through the cable shield are present (e.g. with some tube equipment), in complex grounding situations and/or where extra shielding against strong external electrical interference is required (e.g. in highly electrical noise polluted areas). As such The FIRST ® Metal Screen is

especially suited as an interconnect between (or to or from) tube equipment, for transport of weak signals such as from phono cartridges, microphones or musical instruments and as a long length interconnect for all situations.

4. The SECOND ® is a balanced cable with two separate center groups, each made of 12.000 LSC fibers. Its shield is made of 4 layers: two layers of high quality silver coated copper and two extra layers with LSC saturated foil in direct contact with the two metal layers. The outer jacket again is made of HULLIFLEX ®; a chemically completely inert and impenetrable material without any halogens.
   Especially as a microphone (or even electrical instrument) cable, The SECOND ® performs outstandingly due to the lack of CCD. The very low signal levels cannot be deformed by any mechanical or chemical defects (as being possible with metals) since LSC doesn't contain any of these.

5. The THIRD ® is our latest pure LSC product. It is a 3.5 million LSC fiber constructed single lead made for loudspeaker connections. The typical resistance 0.07 Ohm/m. Sonically its qualities are simply unsurpassed.

Q: Are there other applications for LSC in e.g. audio cables?

A: Yes there are. At the moment the major part of our regular metal cable products have been upgraded with extra conductive layers containing LSC.
We name them ***Hybrids*** since they combine both metal and LSC.
Here, each of the original metal conductors has an extra black coat of LSC saturated material. The saturation is such that the coat exhibits a relative good electrical conductivity. The LSC saturated layer surrounding the metal groups of e.g. a loudspeaker cable is responsible for electrically bridging the minor defects that to a certain amount always remain in metal conductors. The origins of these defects have already been discussed earlier in this paper. The hybrid layer acts as an outer surface impedance controller, so CCD effects are smoothened and the result is a sound quality close to that of our pure LSC cables.
A second complex effect is that radiated magnetic fields in a way are transformed to an electrical current again within the higher impedant conductive layer.
The third positive effect is that the metal conductors are completely sealed from exposure to air. Normally each multistrand metal cable is open to air penetration; with a hybrid jacket there is no further aging by polluted air.
All these aspects together result into a spectacular sonic improvement.

Q: Does LSC have any other advantages?

A: Yes. LSC can be recycled for 100%, so cables like The FIRST ® can be cut, milled and thermally treated to obtain e.g. the coat used in our hybrid products.

Q: What further improvements can be expected with LSC?

A: At the moment we are coating individual metal strands with LSC to further improve the sound quality. Our first cable with this special technology will be named the D - 202 HYBRID.

Q: Does a LSC cable require a burn-in period?

A: From the theoretical point of view the answer is No. But despite this answer, the settlement of the conductive structure needs some time. I many cases (according to the practical experience of many users) one hour is enough to bring out the full sonic potential.

Q: Are there any other technical applications for LSC?

A: Yes, there are many. One of the most interesting applications is supported by the facts that LSC can hardly be destroyed by high temperatures and shows no bending fatigue, so e.g. the coil and the lead-in wires of a tweeter can be made from LSC.
Also electromagnetic shields used in digital equipment can be made from LSC to absorb radiated HF energy. Regarding jitter induced distortion, the timing in digital audio circuitry is very important; any absorption of (radiated) signals without reflections is very beneficial.
Regarding LSC's lack of bending fatigue, another great application (e.g. with our CC - 18 LSC wire) is the use as conductor in robots and medical applications where many movements must be made without failure of the electrical conductors; again LSC is the answer.

Do not hesitate to contact us if you are interested in any of these applications.

Q: Does LSC have any environmental advantages?

A: Yes there are many. To mention a few: The material maintains very stable properties during a much longer lifespan

compared to metal conductors, therefore regular replacement is past history. This means lower energy consumption and metal sources are relieved from producing high volumes of copper cable.
So the total quantity of material to be recycled can be reduced, especially when LSC finds more applications in the industry. From now on we can save our resources and leave the metal in the mines for next generations. The demand for metal as a conductor can be reduced and as a reward the signal transmission quality is improved.
Also LSC is a completely inert non-toxic material. Copper in contrast is toxic in many of its chemical compounds.
So some investment in LSC applications even helps to bring us a cleaner world.

Signed: A.J. van den Hul